

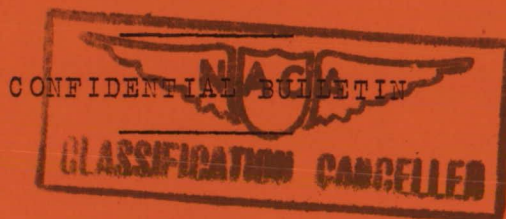
## **General Disclaimer**

### **One or more of the Following Statements may affect this Document**

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

# CASE FILE COPY

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

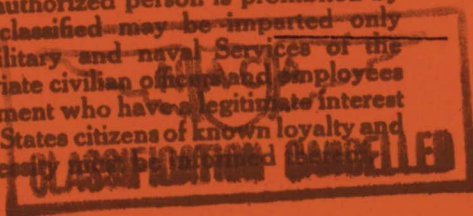


## CONTROL-SURFACE INSTABILITY ON HIGH-SPEED AIRPLANES

By William H. Phillips  
Langley Memorial Aeronautical Laboratory

### CLASSIFIED DOCUMENT

This document contains classified information affecting the National Defense of the United States within the meaning of the Espionage Act, USC 50:31 and 32. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law. Information so classified may be imparted only to persons in the military and naval Services of the United States, appropriate civilian officers and employees of the Federal Government who have a legitimate interest therein, and to United States citizens of known loyalty and discretion who of necessity must be informed.



June 1942

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

CONFIDENTIAL BULLETIN

CONTROL-SURFACE INSTABILITY ON HIGH-SPEED AIRPLANES

By William H. Phillips

Tests of several modern airplanes indicate that control surfaces with a high degree of aerodynamic balance are likely to possess characteristics which make them unsatisfactory or dangerous in high-speed flight. Dive tests made in the spring of 1940 at the NACA on a naval fighter-type airplane illustrate one form of instability that may be encountered. During a dive at an indicated airspeed of 365 miles per hour, the ailerons suddenly overbalanced. The efforts of the pilot to bring the ailerons back to neutral resulted in a violent oscillation of the control stick from side to side. Fortunately, the force required to return the ailerons to neutral was within the pilot's capabilities. A time history of the maneuver is given in figure 1 and typical frames from motion pictures of the cockpit and of the wing, taken during the maneuver, are given in figure 2. In the illustrated case, the occurrence of aerodynamic overbalance was attributed to a slight bulge, approximately 1/16 inch thick, on the lower surface of the leading edges of the ailerons, caused by the installation of additional mass balance ahead of the hinge line. A drawing showing the shape of the bulge is given in figure 3. After this slight protuberance had been eliminated, dives were successfully made at higher speeds.

Another instance of this type of instability has recently been reported for a dive bomber. The airplane was dived successfully with one set of ailerons. When another supposedly identical pair of ailerons was substituted, aileron overbalance occurred in a dive. The ailerons suddenly went from neutral to full deflection as the pull-up was started. The pilot was unable to return the stick to neutral until he had reduced the speed and deflected the trim tab. The ribs of the upward-deflected aileron were found to have buckled as a result of the high loads imposed when the overbalancing occurred, but the principal parts of the aileron and the wing structure fortunately did not disintegrate.

There appears to be a good possibility that erratic hinge-moment characteristics of this type on overhanging balances at high speed are attributable to compressibility effects. The balancing action of a Frise-type aileron, for example, is achieved largely by the high negative pressure on the nose of the upward-deflected aileron. Wind-tunnel tests of airfoils near the critical speed have shown that increases in the peak pressures occur before a shock wave starts to form. A similar change in pressure distribution on a highly balanced aileron might cause a large overbalancing moment to occur at certain speeds in the upper end of the speed range.

The hinge-moment characteristics of control surfaces are known to be greatly influenced by minute changes in their shape at points other than the nose of an overhanging balance. Recent wind-tunnel tests (references 1 and 2) have shown that a slight convexity of the surface, or changes in the thickness of the trailing edge, or a control surface may completely alter the hinge-moment characteristics. The effect of compressibility phenomena may likewise vary greatly with small design changes. For these reasons, the problem of obtaining an exact degree of balance throughout the speed range on the surface controls of a production airplane appears very difficult.

The control surfaces must be almost neutrally balanced, however, in order to give sufficiently light control forces at high speeds. For example, tests on numerous pursuit-type airplanes have shown that, for satisfactory aileron control, a value of  $pb/2V$  of 0.07 should be obtainable with a stick force of 30 pounds at 0.8 the maximum indicated airspeed in level flight. The ratio  $pb/2V$  is the helix angle in radians generated by the wing tip in a roll, where  $p$  is the rolling velocity in radians per second,  $b$  is the wing span in feet, and  $V$  is the true airspeed in feet per second. On a pursuit airplane of 40-foot span, with a maximum indicated airspeed of 300 miles per hour, plain flap-type ailerons would require approximately five times as much stick force as specified. About four-fifths the hinge moment must therefore be counteracted by suitable design of the aerodynamic balance. Inasmuch as the control forces for a given value of  $pb/2V$  vary as the square of the speed and as the cube of a linear dimension for geometrically similar airplanes, the degree of balance becomes increasingly critical as airplanes are made faster and larger. Under such conditions, any slight change in the

hinge-moment characteristics of the system may lead to a dangerously large aerodynamic overbalance. The fact that such overbalance may result in full aileron deflections at maximum permissible diving speed should be considered in connection with the structural design.

In view of the rapidly increasing difficulty in providing satisfactory controllability as airplanes are made larger and faster, a more satisfactory solution of the problem of aerodynamic balancing of control surfaces than is now available appears necessary. It would be desirable to develop balances that depend for their operation on something other than the localized areas of high negative pressure on the control surface. In addition to aerodynamic balances that may avoid this trouble, serious consideration should be given to the possibility of providing plain flap-type surfaces operated by servo or booster mechanisms.

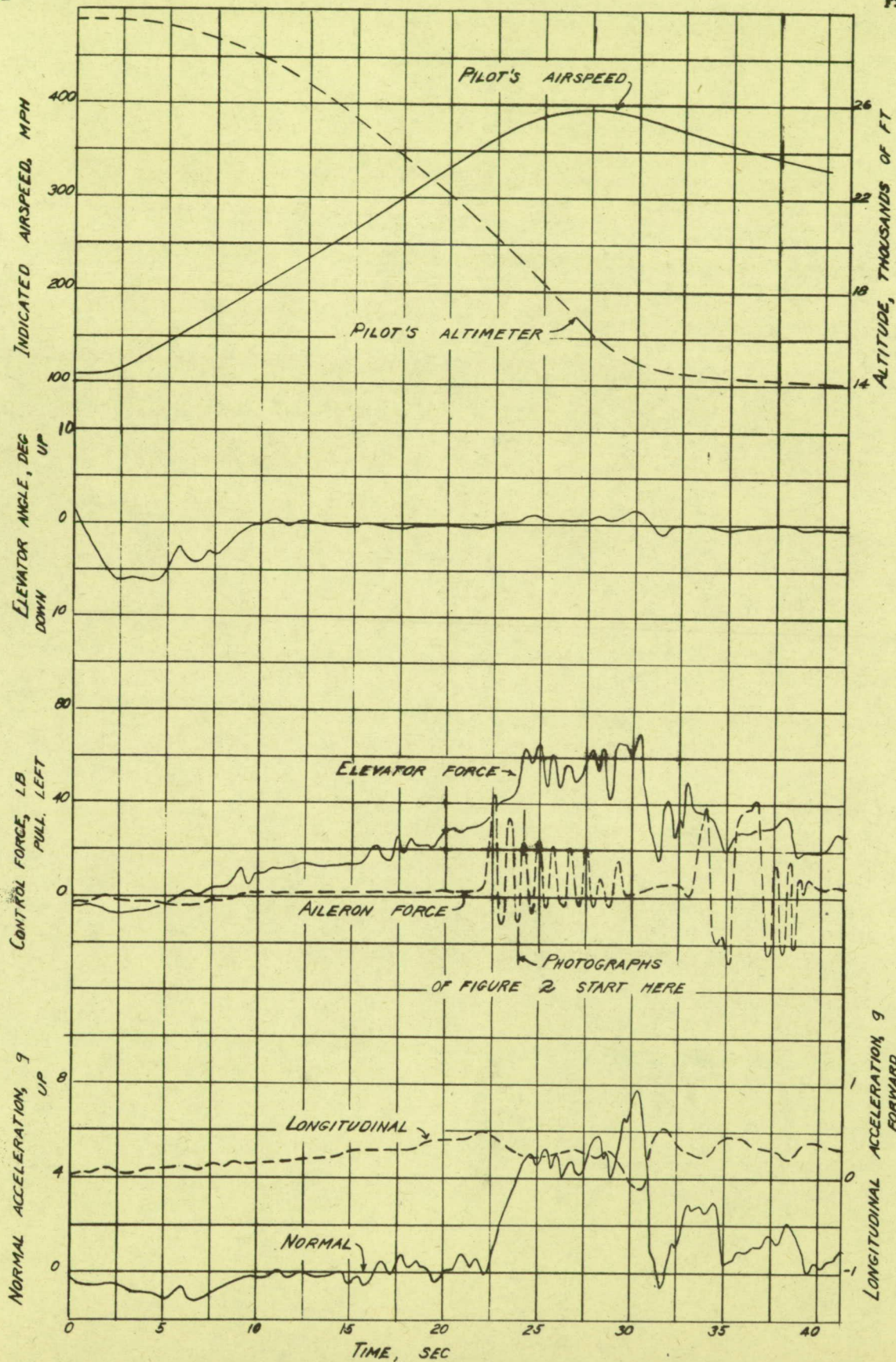
Langley Memorial Aeronautical Laboratory,  
National Advisory Committee for Aeronautics,  
Langley Field, Va.,

#### REFERENCES

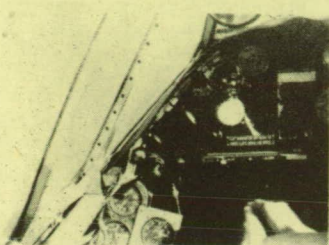
1. Batson, A. S., Burge, C. H., and Greening, J. R.: The Effect of Curvature of Surface and Thickness of Trailing Edge on Aileron Hinge Moments. 5310 S. & C. 1257, N.P.L. (British), Sept. 9, 1941.
2. Jones, Robert T., and Ames, Milton B., Jr.: Wind-Tunnel Investigation of Control-Surface Characteristics. V - The Use of a Beveled Trailing Edge to Reduce the Hinge Moment of a Control Surface. NACA A.R.R., March 1942.



Fig. 1

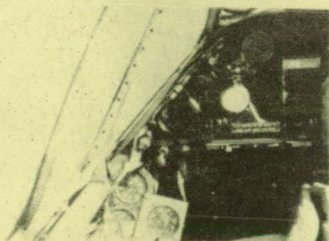






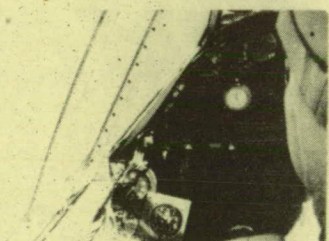
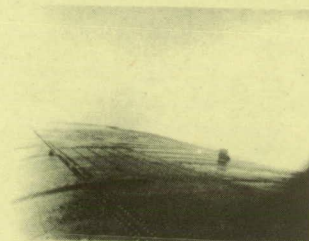
(a)

STICK LEFT  
AILERON DOWN 5 DEG.  
FORCE RIGHT = 10 LBS.  
TIME = 23.8 SEC.



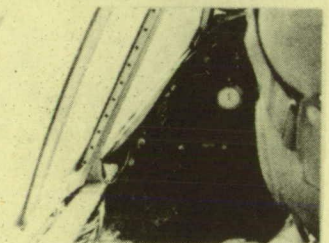
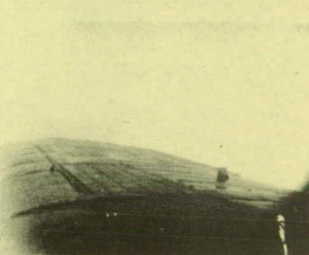
(b)

STICK MOVING RIGHT  
AILERON MOVING UP



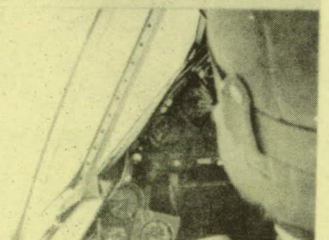
(c)

STICK NEUTRAL  
AILERON NEUTRAL  
FORCE LEFT = 4 LBS.  
TIME = 24.0 SEC.



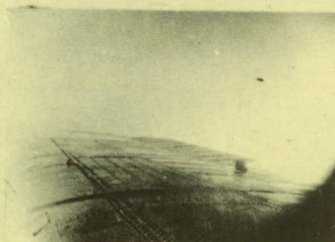
(d)

STICK MOVING RIGHT  
AILERON MOVING UP



(e)

STICK RIGHT  
AILERON UP 10 DEG.  
FORCE LEFT = 24 LBS.  
TIME = 24.2 SEC.



COCKPIT CAMERA

RIGHT WING CAMERA

FIGURE 2.— SEQUENCE OF EVENTS SHOWING AILERON INSTABILITY  
IN ATTEMPTED TERMINAL VELOCITY DIVE.

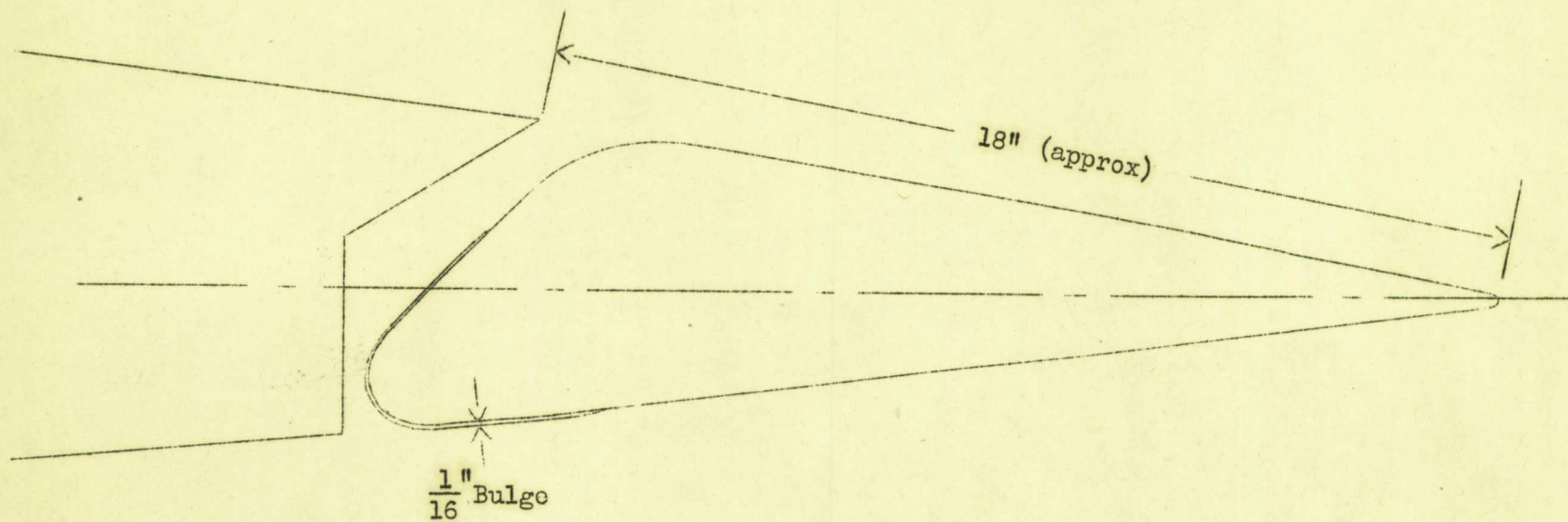


Figure 3.- Diagram showing size and location of bulge on Navy fighter-type aileron.